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P U B L I C A T I O N S
O F T H E
Astronomical Society of the Pacific.

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OBSERVATIONS OF *JUPITER* AND OF HIS SATEL-
LITES WITH THE 36-INCH EQUATORIAL OF
THE LICK OBSERVATORY (1888-1890).

During the years 1888-1890 the phenomena of *Jupiter's* satel-
lites, etc., were observed with the large telescope in the intervals
of other work by Messrs. HOLDEN, SCHAEBERLE, KEELER and
CAMPBELL. (E. S. H.; J. M. S.; J. E. K.; W. W. C.) The fol-
lowing pages give the notes of such observations. The times are
Pacific Standard Times (Greenwich mean times *minus* 8 hours).
The numerous sketches made are here omitted.

The finished drawings made by Mr. KEELER in 1889 have
been printed in *Publ. A. S. P.*, vol. II, p. 15. The photographs
of 1890 are referred to in these *Publications*, vol. III, p. 65 and
in *Mon. Not. R. A. S.*, vol. LI, p. 402 (article by A. STANLEY
WILLIAMS, Esq.).

1888, June 9; *Occultation of 47 Libræ by Jupiter.*

P. s. t. of Immersion $14^h 13^m 50^s.2$, see *Astronomical Journal*,
vol. VIII, p. 64, for details. The star was seen through the at-
mosphere of the planet for more than 80 seconds. E. S. H.

1888, June 22; *Eclipse (reappearance) of Satellite I.* Excellent
vision, Wt. 5; eye-piece 670.

h.	m.	s.	
11	00	11.4;	reappearance, <i>faint</i> . This is not $0^s.5$ late.
11	00	32.1;	satellite twice as bright as at first.
11	00	54.1;	Mr. KEELER notes reappearance with 4-inch finder, power about 25.
11	01	37	; satellite full brightness?
11	02	06	; satellite full brightness?
11	02	31	; satellite full brightness?
11	02	54	; satellite is certainly of full brightness.

1888, June 22 (continued).

But looking at the satellite at $11^h 8^m$ I think the disc is fuller and the satellite even brighter than at $11^h 3^m$. There was as much difference between the satellite when first seen ($11^h 0^m$) and its brightness at $11^h 3^m$ as between a star 14 mag. and one of 6 mag. That is 8 mags. E. S. H.

1888, July 20; *Transit of Shadow of Satellite III.*

Observations by J. M. S. and J. E. K.

- h. m. s.
 9 — —; the shadow is on the following limb, making a notch in the outline. It is oval in shape and twice as long as its indentation in the limb. Its longest dimension points north of *Jupiter's* centre. J. E. K. (Drawing omitted.)
- 9 2 38; a drawing by J. M. S. shows the longest dimension of the shadow to be 3 times the least dimension. The following end of the shadow just touches the east limb of *Jupiter*. On the north and south edges of the shadow is a faint penumbra half as wide as the smallest dimension of the shadow.
- 9 3 57; drawing by J. E. K. The shadow is now an oval with the longest axis about east and west, the shortest about north and south. The longest axis is about twice the lesser one. A penumbra at the *s. p.* end of the shadow is $\frac{3}{4}$ the area of the shadow. A penumbra at the *n. f.* end connects the shadow with the limb of *Jupiter* and is about the area of the shadow itself.
- 9 5 38; drawing by J. M. S. The shadow is oval with its longest axis about *s. p.* and *n. f.* and twice as great as its shortest dimension. The shadow is completely surrounded by a penumbra whose oval contour is similar to that of the shadow and whose axes are nearly those of the shadow itself.
- 9 22 —; drawing by J. M. S. The shadow is still oval as above and is surrounded by a penumbra as above.
- 9 40 —; drawing by J. M. S. A careful estimate by him shows the longest dimension of the shadow to point along a line making an angle 50° *preceding* the polar axis of the planet. The vertex of this angle is at the centre of the shadow which is $2\frac{1}{2}$ diameters of the shadow from *Jupiter's* north limb.

- h. m. s.
 9 40 —; shadow on polar axis of the planet. J. M. S.
 9 49 —; ditto. E. S. H.
 Clouds till 10^h 34^m.
 10 36 —; drawing by J. M. S. through haze. Shadow nearly
 at preceding limb of *Jupiter*. It is nearly 3 times as
 long as it is broad. Its longest axis points about to
 Jupiter's south pole.
 10 40 —; drawing by J. E. K. Shadow elongated: penumbra
 about it.
 10 41 38; drawing by E. S. H. The line of elongation of the
 shadow which is now on *Jupiter's* limb intersects his
 polar axis prolonged one radius of the planet south of
 Jupiter's south limb. No penumbra seen.
 10 47 38; shadow not quite off.
 10 49 57; slight indentation visible. J. M. S.
 10 50 27; shadow gone. J. M. S.

1888, July 23; *Transit of Shadow of Satellite I.*

J. E. K. observer.

The shadow appeared to be perfectly round during its transit; except that at times there was a slight elongation which seemed to be due to atmospheric vibration. A drawing shows a penumbra round the shadow when the latter was one of its own diameters from the preceding limb of the planet (just before egress). Seeing not good. J. E. K.

1888, July 24; *Transit of Red Spot.*

- h. m.
 Seeing very poor.
 9 32.6; drawing made by J. M. S.
 9 58.6; *centre* of red spot nearly to central meridian. E. S. H.
 10 1.6; central now. E. S. H.
 10 5.6; certainly past. E. S. H.
 10 6.6; past. J. M. S.

On the south edge of the red spot is a decided [darker] shade [as drawn] with a white cloud south of it. Another similar cloud and shade are preceding and joined to those described, as if belonging to another red spot. The spot is all veiled over by a white film [as drawn at 10^h 28^m] and there is a central oval space whose longest diameter is $\frac{3}{4}$ of the major axis of the spot, and whose shortest is $\frac{1}{3}$ of the minor axis. This oval space is whiter

than the rest of the interior of the spot, which is of a pale red, veiled over as described.

h. m.

10 22.6 by watch; following edge of spot not yet central. J. M. S.

10 26.6 by watch; central now. J. M. S.

10 28.6 by watch; central now. E. S. H.

1888, July 29; *Transit of Red Spot* (J. M. S.).

8 41.3; transit of first limb.

9 33.3; transit of second limb.

1888, July 30; *Transit (Ingress) of Satellite I.*

h. m. s.

The seeing is very poor.

8 42 —; indentation [or flattening] of *Jupiter's* limb over 5° long.

8 43 —; the satellite is not diminished in brightness.

8 45 47; first contact, very uncertain.

8 47 —; there is a dark shade preceding the satellite.

8 48.3 ; dark shade as above; satellite bisected and seen as well inside as outside the limb.

8 50.1 ; satellite as before; no shade on preceding side of satellite but shades are both north and south of it.

8 51.1 ; satellite certainly inside the limb.

9 7 —; still seen.

9 14 —; still seen. E. S. H.

1888, July 31; *Transit of the Shadow of Satellite II.*

h. m.

7 44 ; drawings by E. S. H. The shadow is elongated $1\frac{1}{4}$ to 1.

The longer axis intersects the polar axis of *Jupiter* prolonged to the north, north of the planet. Calling the angle whose vertex is at this point of intersection and whose sides are *Jupiter's* polar axis prolonged (north) and the major axis of the shadow, A; then $A = 50^\circ$. There is a penumbra on the east and north edges of the shadow.

7 50 ; $A = 30^\circ$. J. E. K.

7 52 ; shadow elongated so that its axis cuts *Jupiter's* polar axis, extended to the north, at a point $80''$ north of *Jupiter's* centre.

7 52 ; a penumbra apparently surrounds the shadow. J. M. S.

7 57 ; $A = 35^\circ$ to 40° . E. S. H. The penumbra is not well seen.

- h. m.
8 1 ; the shadow is best defined on the north and west sides.
It has the same elongation as at 7^h 52^m. J. M. S.
8 0 ; drawing by J. E. K. The satellite sometimes appeared perfectly round, and sometimes elongated. The elongation as well as the penumbra he attributes to atmospheric vibration. A slight elongation in a direction parallel to the planet's limb, near egress, appeared to be real. J. E. K.
8 7.2; internal tangency of shadow and *Jupiter's* limb. J. E. K.
8 11.8; egress (last contact) of shadow. E. S. H.
8 21 ; satellite II appears to be elongated in the same direction as the shadow and as $1\frac{1}{4}$ to 1. The direction of elongation is parallel to the limb of *Jupiter* at 8^h 30^m. The eyepiece used is a single lens giving a power of 5400. Examining satellite III with the same lens it appears nearly round. The objective is in good adjustment. J. M. S. independently confirms the above.

* 1888, July 31; *Eclipse (reappearance) of Satellite I.*

Observer J. M. S.

- h. m. s.
9 29 56 ; satellite first seen.
9 30 56 ; satellite a crescent.
9 31 56 ; satellite not half the disc illuminated yet. The shape is perfectly seen.
9 32 30 ; satellite half illuminated now.
9 33 20 ; satellite three-quarters illuminated now.
9 33 59 ; satellite nine-tenths illuminated now.
9 35 15.5; satellite fully illuminated now.
9 35 — ; satellites I and III, round and steady; satellite II, elongated up and down. Definition of II certainly not as good as on the others. J. M. S.

1888, August 10; *Transit of Red Spot.*

- h. m. s. h. m.
8 45 — to 9 12; drawing by E. S. H.
8 40 42; preceding edge of spot on central meridian.
8 42 42; certainly past.
9 3 57; centre of spot is central on disc.
9 7 42; centre of spot very little past.
9 24 12; following edge central.
9 2 27; spot central from mean of limbs.
9 3 57; spot central by estimation. E. S. H.

1889, June 10; *Egress of Shadow of Satellite I.*

- h. m. s.
 12 43 +; the shadow is round.
 12 53 13; first contact of shadow at egress. The shadow is elliptical with its major axis = $1\frac{1}{2}$ minor axis.
 12 56 8; last contact of shadow. E. S. H.

1889, June 10; *Transit (Egress) of Satellite I.*

The satellite is less than 5" from the limb of *Jupiter*. It is a bright disc, and all around it is a dark shade which may be contrast.

- h. m. s.
 13 5 58; the satellite is slightly elongated in the direction of the major axis of *Jupiter*.
 13 7 8; the satellite is elliptical; major axis = $1\frac{1}{2}$ minor axis. Seeing pretty good.
 13 10 41; internal tangency of limbs of satellite and planet; the former is still elongated.
 13 11 25; first view of part of the satellite outside the planet's disc. E. S. H.

The part of the satellite which is on the disc of the planet has a shade around it, equal to its diameter in breadth.

- h. m. s.
 13 12 50; I is bisected.
 13 15 10; I is round.
 13 15 48; there is still a shade on the following side of the satellite.
 13 16 20; external tangency.

The satellites examined with a high power and the discs of I, II, III, IV look round. III has some kind of marking on its disc, but the night is not good enough to say what form it has. E. S. H.

1889, June 18; *Occultation (reappearance) of Satellite I.*

- h. m. s.
 12 16 52; I, first seen on following limb; seeing poor, Wt. 2.
 12 17 16; see half the satellite's disc through the planet's atmosphere.
 12 19 2; whole disc seen, inside the planet's limb.
 12 19 +; the planet's limb distorted.
 12 20 20; egress. E. S. H.

1889, June 18; *Eclipse of Satellite III.*

- h. m. s.
 13 30 22; the satellite has a round disc, power 390, seeing Wt. 2.
 13 42 52; the satellite appears to be flattened on the following side.
 13 44 18; about half the disc of the satellite is obscured.
 13 45 20; exactly half the disc is obscured as nearly as can be seen.
 13 46 32; disc like a half moon.
 13 53 9; disappeared.

A curious green patch on the middle belt of *Jupiter*. (See drawing of this date by J. E. K.) E. S. H.

1889, June 19; *Transit of Red Spot.*

- h. m. s.
 12 56 29; the preceding end of the red spot is barely past the centre of the disc. E. S. H.

1889, July 2; *Occultation of Satellite I.*

- 13 26 56; contact I, }
 13 29 25; bisection, } Wt. 2, seeing poor.
 13 32 15; contact II, }

The satellite was seen inside the limb as a very brilliant stellar point and disappeared just at second contact. E. S. H.

1889, July 3; *Transit (Egress) of Satellite I and its Shadow.*

- h. m. s.
 12 30 —; the shadow is round, color brownish black. The satellite is brilliant; a little more so than the tops of some white clouds on the same reddish belt (north part of main belt).
 12 36 22; satellite elongated east and west.
 12 39 32; major axis of satellite = $1\frac{1}{2}$ times minor axis, and inclined 5° to 10° to *Jupiter's* equator in direction *s. p.* and *n. f.*
 12 40 22; the shadow *slightly* elongated in same direction.
 12 42 7; major axis of satellite parallel to *Jupiter's* equator; shadow as before.
 12 47 6; internal tangency of limbs of *Jupiter* and satellite I.
 12 47 32; satellite is twice as long east and west as north and south.
 12 48 38; first appearance of any part of the satellite outside the limb of *Jupiter*.
 12 50 49; bisection of satellite.

- h. m. s.
 12 53 57; external tangency of satellite. The time from bisection to second contact is more than the time from first contact to bisection as it should be if the elongation of the satellite is only apparent and due to some action of *Jupiter's* atmosphere. The times are uncertain, however, owing to the poor seeing and low altitude.
- 12 55 14; free space between satellite and limb.
- 13 0 40; shadow *appears* of less diameter than at first.
- 13 2 49; first contact of shadow.
- 13 4 7; shadow bisected.
- 13 4 42; notch perfectly round; well seen.
- 13 6 15; shadow gone.

As may be seen by comparing the times of contacts and of bisections the observations are uncertain on account of poor seeing and low altitude. For the same reasons the apparent changes in the shapes of the satellite and shadow are doubtful from this night's observations. E. S. H.

1889, July 7; *Transit of Shadow of Satellite II; Transit of Shadow of Satellite IV.* Wt. = 3.

- h. m. s.
 9 56 57; shadow of IV makes a notch in the north limb equal to $\frac{3}{4}$ of the diameter of the shadow. Satellite IV looks circular.
- 10 2 17; the shadow is elongated; its major axis points slightly west of the centre of *Jupiter*. It is still a notch in the limb. It seems to have a penumbra about it.
- 10 3 —; the width of the penumbra is $\frac{1}{4}$ of the diameter of the satellite.
- 10 8 7; the shadow is a little east of the north end of *Jupiter's* axis.
- 10 9 27; still a notch; $\frac{3}{4}$ of its diameter inside the limb of the planet.
- 10 10 22; the shadow is on *Jupiter's* axis. The axis of the shadow points a little west of *Jupiter's* centre.
- 10 12 42; ingress of shadow of II first seen.
- 10 14 8; shadow of II half on. Shadow of IV elongated as at 10^h 10^m 22^s.
- 10 14 45; shadow of II all on.
- 10 16 38; shadow of IV as at 10^h 10^m 22^s.

- h. int. s.
 10 17 34; shadow of IV is at least twice as large as that of II. The centre of shadow of IV is much darker than the shadow of II. The shadow of II has a penumbra [drawing].
 10 25 27; the disc of IV is certainly circular. I think there are markings on it, but the vision is not good enough to be certain.
 10 34 —; the longest axis of shadow of IV now appears to be parallel to the axis of *Jupiter*.
 10 39 —; the shadow of IV is about bisected; its longest axis seems to point east of *Jupiter's* centre.
 10 50 57; the shadow of IV (projected on the olive-grey near north pole) has constantly been darker than the shadow of II (projected on a white belt just north of the red equatorial belt).
 10 52 27; the shadow of IV still makes a rounded notch. Probably not more than $\frac{1}{4}$ of it is on the planet.
 10 55 57; the shadow of IV is a faint undulation in the limb.
 10 57 27; ditto.
 10 58 57; ditto.
 11 0 57; shadow of IV no longer visible.
 11 59 —; II is quite bright; three of its own diameters from the limb.
 12 6 18; internal contact of II.
 12 9 12; satellite about bisected.
 12 9 39; satellite bisected.
 12 12 9; about last contact.
 12 12 54; last contact of II. The disc of II is all outside and it seems not more than $\frac{1}{2}$ the diameter of I.
 12 14 —; II seems to increase in brightness all the time.
 12 18 —; II seems at least twice as bright as when fairly clear of the limb. (Contrast? atmosphere of planet?) E. S. H.

Colors of the Satellites.

- I is fiery yellow, E. S. H.; same as III, J. E. K.; redder than III, E. S. H.
 III is strong yellow, E. S. H.; golden yellow, J. E. K.
 IV is pale lemon yellow, E. S. H.; a pale yellowish white, J. E. K.

1889, July 11; *Transit of Red Spot.*

h. m. s.
11 32 9; red spot central.
11 37 —; red spot certainly past transit.

On this night (and on subsequent occasions) attempts were made to measure the distance apart of two objects on *Jupiter* (*a*) at or near the limb (*b*) at the centre, with the object of comparing the effect of *Jupiter's* atmosphere in the two cases. When the planet is higher, I think this can be done, but I have had no success during the present opposition. E. S. H.

1889, July 11; *Eclipse (reappearance) of Satellite II.*

h. m. s.
12 19 24; first glimpse of II.
12 23 15; satellite seems to be of full brightness. The disc is round.

The outline of the shadow of *Jupiter* is not seen on the disc of II. At 12^h 19^m 24^s the satellite was just barely visible—say 17 magnitude, and it gradually increased in brightness till 12^h 23^m, and very likely even after that time. E. S. H.

1890, August 17. Dark markings on *Jupiter's* satellite III. The seeing was average. Eye-pieces 360 and 520 were employed. No markings were seen at any time on satellites I, II, IV. At 9^h 55^m P. s. t. a dark marking was seen by E. S. H. on III, extending from the centre to the *north* limb. The marking was all to the *east* of a *north* and *south* diameter. It was seen (and independently drawn) by W. W. C. exactly as by E. S. H., except that for W. W. C. it terminated before reaching the north limb. Its greatest dimension east and west was $\frac{1}{4}$ of the diameter of III. There is no doubt whatever regarding its existence. At 11^h 40^m P. s. t. both observers are certain that the marking is further *south* and further *east* on the disc. The shape of the marking not so well seen as before. If the spot is a part of the surface of III and turns with it, the rotation period of this satellite is short. E. S. H. and W. W. C.